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Applicability of High-Rise™ Hog Housing for Finishing Operations

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Summary and Implications

The design of High-Rise™ swine facilities allows the generation of a solid, manure-laden material from hogs raised in confinement housing with slatted floors. The volume of manure that must be handled annually can be reduced through continuous moisture loss that takes place within the system's drying bed and recycling of bed material. Recycling typically involves mixing material twice a year — at the end of finishing periods. Moisture contents of twice-recycled manure-laden bed material ranged between 55-65% with continuous aeration for three years of production. This moisture range makes the material acceptable directly as feedstock for composting. Ammonia emissions should be similar to those from deep-pit facilities. However, the levels of other problematically odorous gases should be reduced most of the time due to the generally aerobic nature of the drying bed. Hydrogen sulfide was seldom detected within the building using readily available sensing equipment (i.e. H_2S < 0.3 ppm) even during handling of the manure-laden bed material, and was never measured at more than 4 ppm, which is promising from a safety standpoint. Data collected from six production groups indicated that average daily gain and feed efficiency of finishing pigs in the High-Rise™ facility were equal to or possibly better than that of those produced simultaneously in 11 nearby conventional facilities with an identical source of pigs and the same contract-feeding arrangement. Construction of such a facility incurs additional costs associated with purchasing, installing and operating the aeration system and paying some proprietary fees. With these added costs (+15-20% initial), this system is projected to be a viable alternative mainly for those operations having a combination of special criteria/ constraints, including: relatively high risk of polluting local waterways or water supply; long manure-hauling distances to fields; access to markets for solid manure or compost feedstock; some, but not tremendous, pressure to limit odor generation; and/or limited water availability.

Introduction

Environmental, neighbor and economic pressures have encouraged pork producers to investigate options that are available for housing their pigs, especially growing-finishing pigs. One recent development in swine housing is the High-Rise™ concept. This housing system was designed to solidify hog manure within a slatted-floor production facility. A second goal was to improve the quality of air inside and around the building — with the expected results being improved pig performance and less potential for neighbor complaints about odor.

Water Quality

Liquid manure systems have been targeted as environmental polluters based upon some real evidence and considerable amounts of negative perception. Handling manure as a solid does not eliminate the potential for pollution or neighbor concerns, but in some circumstances, it can reduce these pressures substantially. When applying dilute manures, especially effluent from lagoons, onto land, over-application of water can be a problem. Soils may be brought close to or beyond saturation, which increases the likelihood of surface runoff and tile outflow, both of which can pollute surface waters. Light soils are prone to rapid percolation and potential groundwater contamination. Solid manures can be applied at rates that meet soil nutrient needs without greatly affecting soil moisture levels.

A second advantage of handling solid manure is that the manure becomes more transportable. Systems for handling liquid manure achieved wide acceptance because manure could be handled with pumps with minimal labor input. Liquid manure is easily transported and applied onto land that is adjacent to the primary farmstead. However, requirements for pumping and conveying liquid manure can quickly become unwieldy if the material must be moved longer distances, waterways or other natural features must be crossed, or public roadways must be used or traversed. Solid manure can be readily loaded onto trucks at much higher dry matter and nutrient densities, which gives it greater hauling value.

Nonfarm people usually associate solid manure as being a more desirable manure product than liquid manure. From the perspective of those who might be in the market to purchase manure, more nutrients and organic matter can be obtained from solid manure without the mess that is associated with liquid manure.

Air Quality

Farm neighbors and other public citizens have raised concerns over odors from animal production, especially from larger swine facilities. Few producers can ignore this issue and expect to be readily accepted by their

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Figure 1. High-Rise™ Hog Building – 4-M Farms research/demonstration facility.

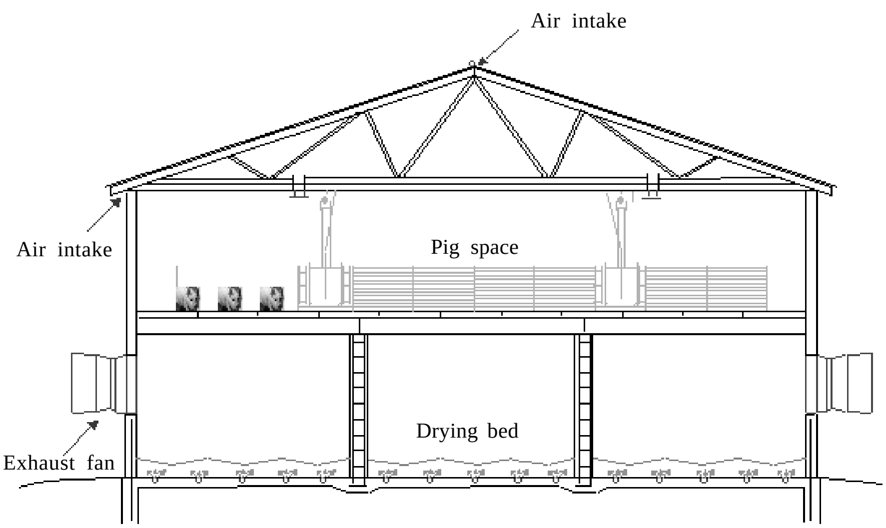


Figure 2. Cross-section view of commercial version of High-Rise™ finishing facility.

local communities in the future. Given the pace of changes in the rural landscape, the greater mobility of the citizenry, and increased ideological separation of those from farm and nonfarm backgrounds, the attention given to odors can only be expected to increase.

Aeration of manure is an odor-control strategy that has been implemented in a number of different systems. The premise is that the products of aerobic decomposition should contain significantly lower levels of odorous hydrogen sulfide and volatile organic compounds than would be produced by anaerobic bacteria. Therefore, the exhaust air from a facility that utilizes aeration should be less odorous than that from production facilities storing liquid manure.

Air quality inside production facilities is important for achieving good pig performance and associated profit potential. The health and safety of operators/employees also are impacted by indoor air quality. Numerous studies have associated high ammonia levels with respiratory dysfunction and reduced performance. Hydrogen sulfide is characterized as a poisonous gas that is known for its presence in confined manure storage areas.

Materials and Methods

System Design and Description.

4-M Farms built the first High-Rise™ hog facility (Figure 1) in Darke County, Ohio in 1997-98 with a capital-improvements (construction) grant from the Ohio Department of Administrative Services. This demonstration/research building was built to test the concept of the facility's design, in which manure at 90% moisture would be partially stabilized and dried in place on a bed of bulking agents (wood shavings, sawdust ground pallets, paper, straw, cornstalks, corncobs, etc.;). The first batch of pigs was placed in the facility in July 1998.

Although labor efficiency, pig performance, and construction costs were considered to be important, they did not drive the design. The intended result was a unique design that would be competitive with other facilities when analyzed on a total system basis, but would be more desirable from an environmental standpoint.

The design of this facility incorporated several significant variations on design concepts of high-rise layer (poultry) facilities, one of the most significant being a patented aeration system or plenum, which is used to aerate, dry, and solidify the manure. Pigs are housed in the upper story on slats (Figure 2). A layer of bulking material is placed in the lower story before pigs are brought into the facility. Manure falls through the slatted floor, into the lower story, and onto the drying bed. The bulking material adsorbs free liquids, contains the manure, and allows air to flow through the bed. Airflow is directed into the bed from below, drying the material and supplying oxygen to the system. Once moistened air leaves the bed, it combines with ventilation air supplied to the pigs and is exhausted by fans located in sidewalls of the lower story.

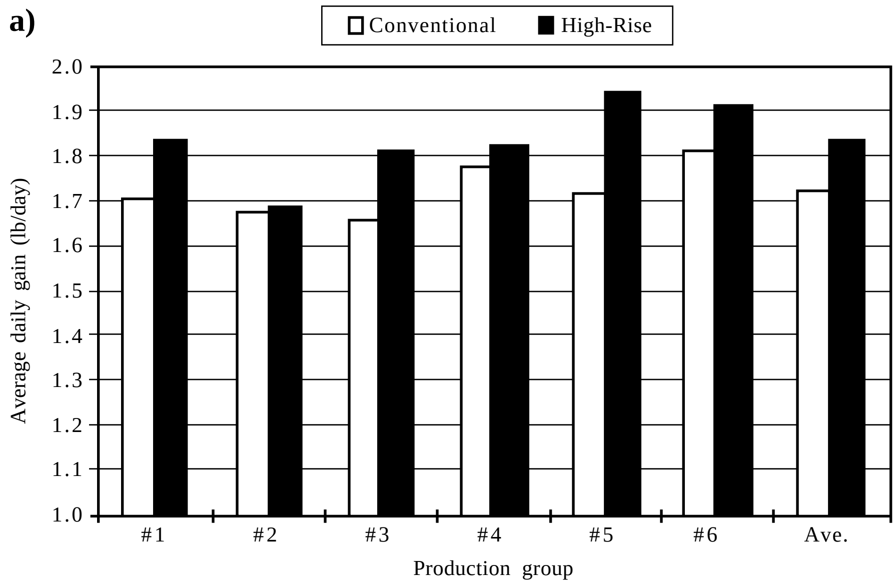
The most visible difference between a High-Rise™ facility and conventional swine production facilities is that the structure is taller. The floor of the lower story can be constructed at ground level. No pit is constructed into the ground meaning excavation requirements are reduced. Large access doors are included to allow implements access into the lower story. A ramp must be constructed to facilitate loading and unloading pigs. Construction must provide for the installation of the aeration system, especially the in-floor plenum (system of air ducts). Other construction features are similar to those for conventionally designed slatted-floor facilities. Wet-dry feeders must be used in a High-Rise™ facility to limit water wastage.

The ventilation systems in these facilities are distinctly different from those of facilities with conventional mechanical ventilation systems in that all of the exhaust fans are located in the lower story of the building. Air is drawn into the building through openings in the attic. Tempered air is pulled from the attic into the pig space in the upper story through baffled ceiling inlets. There is typically one inlet on each side that runs almost the length of the production room. This design directs jets of air outward from the room inlets along the ceiling of the room. Fresh air mixes with room air prior to being drawn through the slatted flooring into the lower story. Since the upper story is nearly airtight other than the ceiling inlets and slatted flooring, the bulk movement of air is downward, with ventilation air moving into the lower story before being exhausted from the building.

Data Collection

Modern monitoring and control systems for maintaining desired temperatures within the pig space were built into the research/demonstration facility. Indoor (upper story) and outdoor dry-bulb air temperatures, dry-bulb air temperatures at eight locations distributed evenly around the pig space, and fan operation data were collected on a nearly continuous basis. Ammonia, hydrogen sulfide and carbon dioxide concentrations were measured at three locations within each story and from the exhaust fans located around the building perimeter using Dräger tubes (w/hand pump). These measurements were taken roughly every other week during the first six growouts. Grab samples of mixed manure-laden bed material were collected during several building cleanouts.

Pig performance from this facility was compared to that of pigs within 11 nearby conventionally designed finishing facilities. All of the conventional facilities had fully slatted floors, were either tunnel-ventilated or naturally ventilated, and had deep pits. All 12 facilities were stocked with contract pigs from the same source and were on the same feeding program. Production schedules were pre-set by the contractor to meet packer schedules, which resulted in growout periods being set initially for the same number of days. The growout periods overlapped, but began at different times over about a 3-week period to accommodate production schedules. The contractor recorded feed delivery and pig weights, along with producer records of death losses and culls.



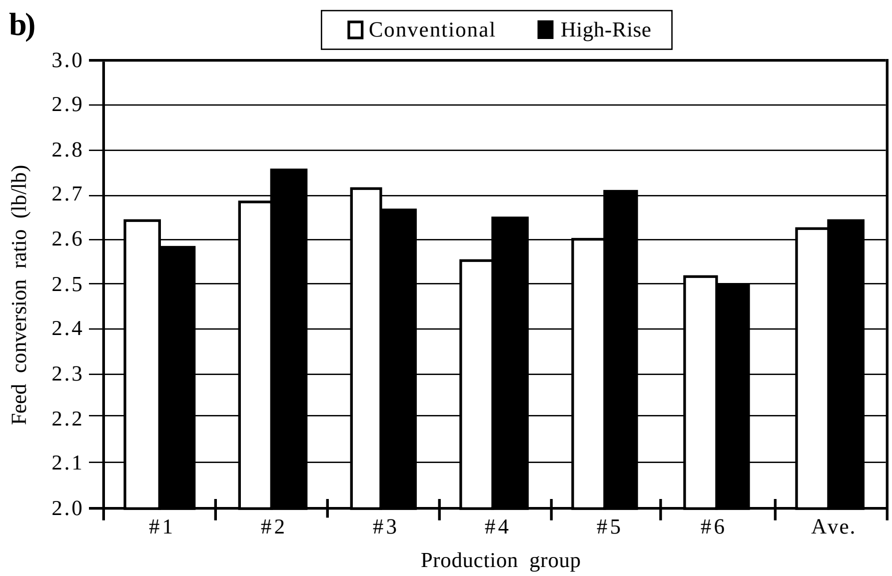


Figure 3. Growth rate (a) and feed efficiency (b) of pigs raised in the High-Rise™ facility compared to pigs raised in conventional facilities.

Results and Discussion

Manure/Bed Material

Wood shavings and corn stover performed well as bulking materials, especially in terms of maintaining their porosity. Sawdust and shredded newspaper have not performed well in spot trials (where they were used under only one or two pens) because the surfaces

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of both materials matted over quickly, resulting in poor flow of manure downward and air upward. Chopped straw was acceptable as a bulking agent.

Bed material could be recycled twice, meaning it was used for three growouts or for more than a year. After the pigs were removed, the material was mixed and allowed to heat for a few days. After being used for three growouts, about 2.5-3 ft of material remained. On a volume basis, about 65% less material had to be transported and utilized as compared to liquid manure in a deep pit. The manure-laden bed material is handled as a solid using front-end loaders and trucks.

Although considerable drying of the bed material took place, composting did not occur without mixing. The manure-laden material quickly heated after it was mixed. The microbial inactivity before and activity following mixing were documented using temperature probes. Most of the manure-laden bed material has been composted on site for distribution by a manure brokerage. Other nearby producers with commercial High-Rise™ buildings planned to apply their material to land and incorporate it without composting the material.

The characteristics of the manure-laden bed material varied with the extent of recycling done, the choice of bed material used, and the location that was sampled. In general, however, the nutrient density of the bed material was much higher than that of liquid manure from conventional facilities. While the nutrient density was increased, no change in the total amounts of phosphorus and potassium (or other minerals) present in the material was found nor was any change expected. Nutrient analyses indicated that nitrogen losses from the material (on a total mass basis) were on the same scale as losses from manure stored in deep pits. Much of this nitrogen loss occurs through volatilization as ammonia and emission from the building in the exhaust air.

Thermal Conditions

Average air temperatures within the upper story were maintained within a fairly narrow band around the desired indoor temperature during cool and cold weather, $\pm 2^oF$ during 20^oF swings in outdoor temperature. Individual temperatures throughout the pig space were also quite stable. During the summer, all fans were operated at full capacity, which resulted in excellent air quality within the pig space. During very hot weather, mist was evaporated in the inlet air streams to provide supplemental cooling. Sprinkling is not compatible with this housing system since water wastage needs to be minimized.

Gas Levels

Measured concentrations of ammonia within the pig space were consistently below 20 ppm which is the eight-hour exposure threshold limit established (by OSHA) for building occupants. Over the two years in which gas measurements were made, the average concentration was 4.3 ppm and readings ranged from undetectable to 19 ppm. Ammonia concentrations in the pig space of conventional finishing facilities have been reported to range from about 5 ppm during summer to 10-20 ppm during winter. Concentrations of ammonia within the lower story regularly exceeded this limit and one reading exceeded 120 ppm. The average concentration downstairs was 23.3 ppm. Exhaust air concentrations had an overall mean of 17.9 ppm.

The pronounced trend was for ammonia levels to increase during cold weather when ventilation rates were at a minimum. The increased rate of ammonia generation under slightly warmer conditions was more than offset by highly elevated rates of ventilation. The ammonia levels within the lower story could be irritating during winter, causing watery eyes, odor, and slight respiratory distress when the area was occupied for several minutes.

Hydrogen sulfide was not found in measurable quantities within the pig space. Additionally, no odor or other sign of its presence was noted upstairs. Occasionally, hydrogen sulfide was detected at concentrations not exceeding 0.5 ppm downstairs. Hydrogen sulfide is an odorous gas (rotten-egg smell) and is lethal at high concentrations. Low concentrations of hydrogen sulfide in the exhaust air bode well for addressing concerns about odor.

Gas measurements were also taken during consecutive cleanouts during the summer and fall of 2000. Ammonia concentrations during cleanout were similar to those during the last weeks with pigs in the building and emissions were about the same as that during production in the summer. Hydrogen sulfide was detected more frequently during cleanout than during production, but average levels were still well below 1 ppm and only one reading was above that level (3.6 ppm).

Pig Performance

Growth rate of swine raised in the High-Rise™ appeared to exceed the average rate for the 11 comparison facilities for the first six growouts (Figure 3) based upon contractor data (Cooper Farms, Inc.). Overall average daily gain was 1.84 vs 1.73 lb/day and pigs were marketed at 115 vs 119 days in the High-Rise™ and conventional facility, respectively. Feed efficiency in the High-Rise™ facility was similar to that of the comparable conventional facilities (2.64 vs. 2.62). Pigs within the High-Rise™ facility grew rapidly and had reasonable feed conversion ratios. The fairly stellar performance can probably be attributed to a combination of good management, a good source of pigs, new facilities, and reasonably good air quality. Other than using wet/dry feeders, there is little difference in managing pigs in a High-Rise™ facility than in conventional, fully slatted facilities. Any effects of feeder type were not evaluated in this investigation.

Death losses exceeded those of the comparable production facilities (4.2% vs 3.2%), largely due to two enteric disease outbreaks. Since the facility was available for tours and demonstration purposes, it was difficult to maintain tight biosecurity on the premises even though access to the pig space was restricted. Respiratory ailments were not evident in the pigs.

Systems Perspective

The High-Rise™ concept for raising pigs shows potential for addressing some important environmental concerns. There are additional initial and operating costs associated with the facility, however. Extra initial costs include proprietary fees and the cost of the aeration fans and installing the in-floor aeration system. Operation of the aeration fans consumes electrical energy at a rate that is about that required to operate the minimum-ventilation system. Therefore, the economics of utilizing such a facility design needs to be evaluated as part of a total systems analysis. Such an analysis would include social and environmental costs, to the extent to which they are known or can be estimated.

Conclusions

After monitoring the operation of a High-Rise™ hog finishing facility for nearly three years, it is evident that such facilities can produce a solid manure product. With recycling of the drying bed material, substantially less material volume needs to be handled and moisture contents near 60% may be expected. Additionally, the following conclusions were made concerning the performance of this type of facility for raising pigs:

- Air quality for the pigs, in terms of the thermal and gaseous environments, should be as good or better than that of conventional deep-pit facilities, but gas levels will probably exceed those present within facilities with flush systems since the manure remains within the facility;
- There appear to be benefits for odor control and safety due to the aerobic conditions that are maintained within the drying bed, but considerable ammonia will still be emitted and common safety measures should still be practiced when handling manure-laden bed material within the facility; and
- Pig performance should not differ from conventional fully slatted facilities given reasonable management.

[1]Richard Stowell is an assistant professor in the Biological Systems Engineering Department. He worked in this topic area while at, and with support from, The Ohio State University, Columbus, Ohio.